Chapter 3. Water Quality

INTRODUCTION

The City of San Diego monitors water quality along the shoreline and in offshore ocean waters for the region surrounding the South Bay Ocean Outfall (SBOO). This aspect of the City's ocean monitoring program is designed to assess general oceanographic conditions, evaluate patterns in movement and dispersal of the SBOO wastewater plume, and monitor compliance with water contact standards as defined in the 2001 California Ocean Plan (COP) (see Chapter 1). Results of all sampling and analyses, including COP compliance summaries, are submitted to the San Diego Regional Water Quality Control Board in the form of monthly receiving waters monitoring reports. Densities of fecal indicator bacteria (FIB), including total coliforms, fecal coliforms, and enterococcus, are measured and evaluated along with data on local oceanographic conditions (see Chapter 2) to provide information about the movement and dispersion of wastewater discharged to the Pacific Ocean through the outfall. Evaluation of these data may also help to identify other point or non-point sources of bacterial contamination (e.g., outflows from rivers or bays, surface runoff from local watersheds). This chapter summarizes and interprets patterns in seawater FIB concentrations collected for the South Bay region during 2009. In addition, this chapter assesses remote sensing data to provide further insight into the transport potential in coastal waters surrounding the SBOO discharge site.

Materials and Methods

Field Sampling

Seawater samples for bacteriological analyses were collected at a total of 39 shore, kelp bed, or other offshore monitoring sites during 2009 (Figure 3.1). Sampling was performed weekly at 11 shore stations to monitor FIB concentrations in waters adjacent to public beaches. Eight of these stations (S4, S5, S6, S8, S9, S10, S11, S12) are located between the USA/Mexico border and Coronado, southern California and are subject to COP water contact standards (see Box 3.1). The other three shore stations (S0, S2, S3) are located in Mexican waters off northern Baja California and are not subject to COP requirements. Three stations located in nearshore waters within the Imperial Beach kelp forest were also monitored weekly to assess water quality conditions and COP compliance in areas used for recreational activities such as SCUBA diving, surfing, fishing, and kayaking. These include stations I25 and I26 located near the inner edge of the kelp bed along the 9-m depth contour, and station I39 located near the outer edge of the kelp bed along the 18-m depth contour. An additional 25 stations located further offshore in deeper waters were sampled once a month in order to monitor FIB levels and estimate the spatial extent of the wastewater plume. These offshore stations are arranged in a grid surrounding the discharge site distributed along the 9, 19, 28, 38, and 55-m depth contours (Figure 3.1). Sampling of these offshore stations generally occurs over a 3-day period each month.

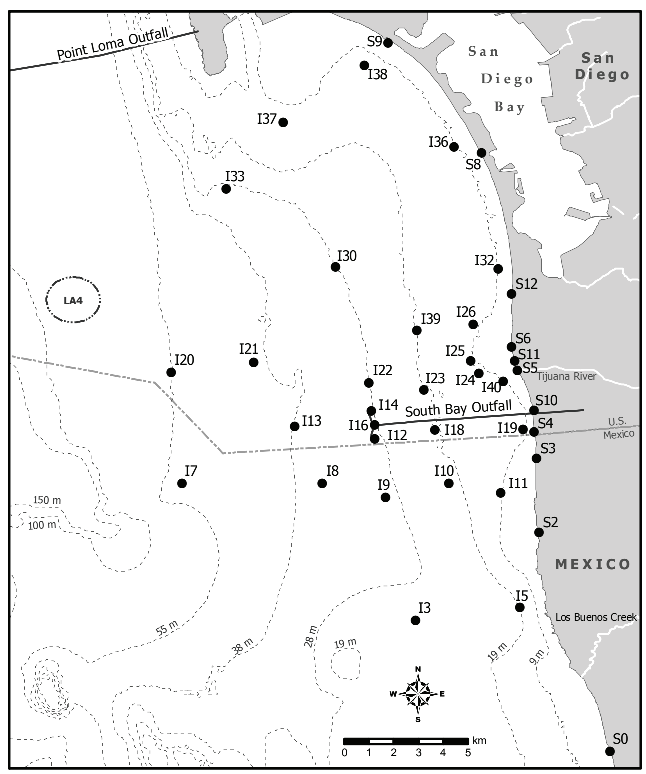

Figure 3.1
Water quality monitoring stations for the South Bay Ocean Outfall Monitoring Program.

Box 3.1

Bacteriological compliance standards for water contact areas, 2001 California Ocean Plan (SWRCB 2001). CFU = colony forming units.

(a) *30-day Total Coliform Standard* — no more than 20% of the samples at a given station in any 30-day period may exceed a concentration of 1000 CFU per 100 mL.

(b) *10,000 Total Coliform Standard* — no single sample, when verified by a repeat sample collected within 48 hrs, may exceed a concentration of 10,000 CFU per 100 mL.

(c) *60-day Fecal Coliform Standard* — no more than 10% of the samples at a given station in any 60-day period may exceed a concentration of 400 CFU per 100 mL.

(d) *30-day Fecal Geometric Mean Standard* — the geometric mean of the fecal coliform concentration at any given station in any 30-day period may not exceed 200 CFU per 100 mL, based on no fewer than five samples.

Seawater samples for the shore stations were collected from the surf zone in sterile 250-mL bottles. In addition, visual observations of water color, surf height, human or animal activity, and weather conditions were recorded at the time of collection. The samples were then transported on blue ice to the City of San Diego's Marine Microbiology Laboratory (CSDMML) and analyzed to determine FIB concentrations (i.e., total coliform, fecal coliform, and enterococcus bacteria).

Either an array of Van Dorn bottles or a rosette sampler fitted with Niskin bottles was used to collect seawater samples at each of the kelp bed and other offshore stations. Samples were collected at three discrete depths for the above FIBs (i.e., total and fecal coliforms, enterococcus) and total suspended solids (TSS), whereas oil and grease (O&G) samples were only collected from surface waters. Aliquots for each analysis were drawn into appropriate sample containers. All bacterial seawater samples were refrigerated onboard ship and transported to the CSDMML for subsequent processing and analysis. TSS and O&G samples were taken to the City's Wastewater Chemistry Services Laboratory for analysis. Visual observations of weather and sea conditions, and human or animal activity were also recorded at the time of sampling.

Laboratory Analyses and Data Treatment

All bacterial analyses were performed within 8 hours of sample collection and conformed to standard membrane filtration techniques (see APHA 1998). The CSDMML follows guidelines issued by the United States Environmental Protection Agency (U.S. EPA) Water Quality Office, Water Hygiene Division, and the California State Department of Health Services (CDHS) Environmental Laboratory Accreditation Program (ELAP) with respect to sampling and analytical procedures (Bordner et al. 1978, APHA 1998).

Procedures for counting colonies of indicator bacteria, calculation and interpretation of results, data verification and reporting all follow guidelines established by the U.S. EPA (Bordner et al. 1978) and APHA (1998). According to these guidelines, plates with FIB counts above or below the ideal counting range were given greater than (>), less than (<), or estimated (e) qualifiers. However, these qualifiers were dropped and the counts treated as discrete values when calculating means and in determining compliance with COP standards.

Quality assurance tests were performed routinely on seawater samples to ensure that sampling variability did not exceed acceptable limits. Duplicate and split bacteriological samples were processed according to method requirements to measure intrasample and inter-analyst variability, respectively. Results of these procedures were reported in City of San Diego (2010).

Bacteriological benchmarks defined in the 2001 COP and Assembly Bill 411 (AB 411) were used as reference points to distinguish elevated FIB values in receiving water samples discussed in this report. These benchmarks are: (a) >1000 CFU/100 mL for total coliforms; (b) >400 CFU/100 mL for fecal coliforms; (c) >104 CFU/100 mL for enterococcus. Data were summarized for analysis as counts of samples in which FIB concentrations exceeded any of these benchmarks. Furthermore, any water sample with a total coliform concentration ≥1000 CFU/100 mL and a fecal:total (F:T) ratio ≥0.1 was considered representative of contaminated waters (see CDHS 2000). This condition is referred to as the fecal:total ratio (FTR) criteria herein. In addition, statistical analyses were conducted to determine if the proportion of shore samples with elevated FIBs or samples that met the criteria for contamination correlated with rainfall on an annual basis between 1996 and 2009. To meet the assumption of linearity and homogeneity of variances for the correlations, FIB and FTR data were arcsine transformed. This relationship was further investigated by comparing elevated total coliform concentrations to aerial and satellite images produced by Ocean Imaging of Solana Beach, California (Ocean Imaging 2010).

Results and Discussion

Shore Stations

Concentrations of indicator bacteria generally were lower along the South Bay shoreline in 2009 than in 2008 (see City of San Diego 2009), which likely reflects less rainfall during the past year (i.e., 5.5 inches in 2009 vs. 12.1 inches in 2008). During 2009, monthly FIB densities averaged from < 2 to 13,350 CFU/100 mL for total coliforms, <2 to 9012 CFU/100 mL for fecal coliforms, and <2 to 7025 CFU/100 mL for enterococcus (Appendix B.1). As expected, most samples with elevated FIBs (81 of 85 samples) and that exceeded FTR criteria (40 of 42 samples) were collected in the wet season primarily during January, February, and December (Table 3.1; Appendix B.2). These high FIB counts tend to correspond with turbidity plumes from the Tijuana River and Los Buenos Creek (in Mexico), which have been observed repeatedly over the past several years following rain events (e.g., see City of San Diego 2008, 2009). For example, a MODIS satellite image taken February 18 showed turbidity plumes encompassing all of the SBOO shore stations, 10 of which had elevated total coliform concentrations on the previous day (Figure 3.2). While the image in this figure was not taken on the same day the bacterial samples were collected, the turbidity

Table 3.1

The number of samples with elevated bacteria collected at SBOO shore stations during 2009. Elevated FIB = the total number of samples with elevated FIB densities; contaminated = the total number of samples that meet the fecal:total coliform ratio criteria indicative of contaminated seawater; Wet = January–April and November–December; Dry = May–October; *n* = total number of samples. Rain data are from Lindbergh Field, San Diego, CA. Stations are listed north to south from top to bottom.

		Season		
Station		**Wet**	**Dry**	**Total**
S9	Elevated FIB	—	—	—
	Contaminated	1	—	1
S8	Elevated FIB	3	—	3
	Contaminated	2	—	2
S12	Elevated FIB	4	—	4
	Contaminated	2	—	2
S6	Elevated FIB	6	—	6
	Contaminated	2	—	2
S11	Elevated FIB	5	—	5
	Contaminated	5	—	5
S5	Elevated FIB	11	—	11
	Contaminated	9	—	9
S10	Elevated FIB	12	—	12
	Contaminated	6	—	6
S4	Elevated FIB	11	—	11
	Contaminated	6	—	6
S3	Elevated FIB	10	—	10
	Contaminated	2	—	2
S2	Elevated FIB	7	1	8
	Contaminated	2	—	2
S0	Elevated FIB	12	3	15
	Contaminated	3	2	5
	Rain (in)	5.43	0.07	5.50
Total	Elevated FIB	81	4	85
Counts	Contaminated	40	2	42
	n	286	286	572

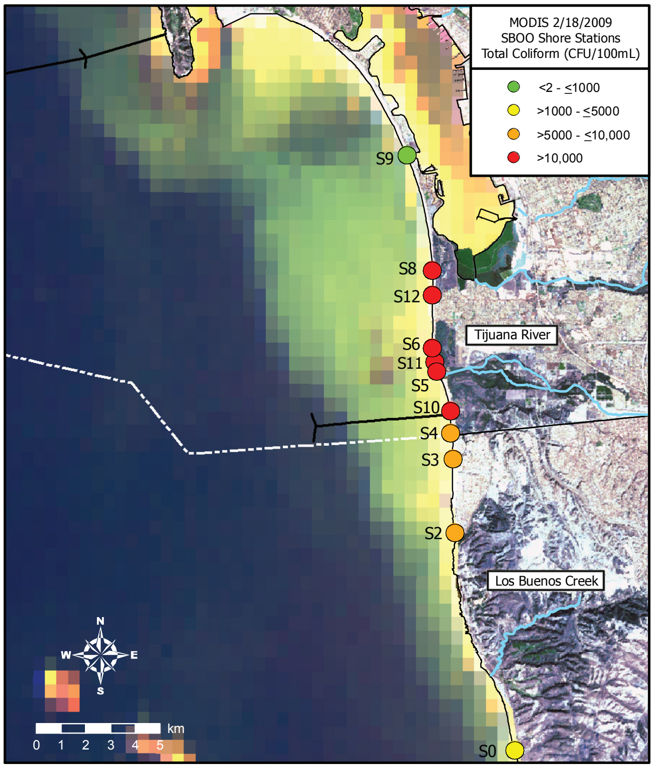

Figure 3.2
MODIS satellite image showing the SBOO monitoring region on February 18, 2009 (Ocean Imaging 2010) combined with total coliform concentrations at shore stations sampled on February 17, 2009. Turbid waters from the Tijuana River and Los Buenos Creek can be seen moving northwest along the coastline, overlapping southern stations with higher levels of contamination. Waters are relatively clear over the outfall discharge site.

plume that is evident likely started earlier in the week due to a major storm that began February 16.

The general relationship between rainfall, elevated FIBs, and the number of contaminated samples has remained consistent since monitoring began in 1995 (see City of San Diego 2009). This relationship is further supported by the strong correlation between the proportion of samples with elevated FIBs and annual rainfall from 1996 to 2009 ($r = 0.72$, $p = 0.004$, Figure 3.3A) and between the proportion of samples that met the FTR contamination criteria and annual rainfall for the same time period ($r = 0.81$, $p < 0.001$, Figure 3.3B). In 2009, this relationship was particularly evident at stations S3–S6, S10, S11 near the Tijuana River and stations S0 and S2 near Los Buenos Creek (see Table 3.1). Historically, elevated FIB densities have occurred much more frequently at these eight shore stations than stations S8, S9, and S12 located further north (see City of San Diego 2007). It is well established that contaminated waters originating from the Tijuana River and Los Buenos Creek are likely sources of bacteria during periods of increased flows (e.g., during storms or extreme tidal exchanges) (see Noble et al. 2003, Largier et al. 2004, Gersberg et al. 2008, Terrill et al. 2009). Such contaminants may originate from various sources, including sod farms, surface runoff not captured by the canyon collection system, the Tijuana estuary (e.g., decaying plant

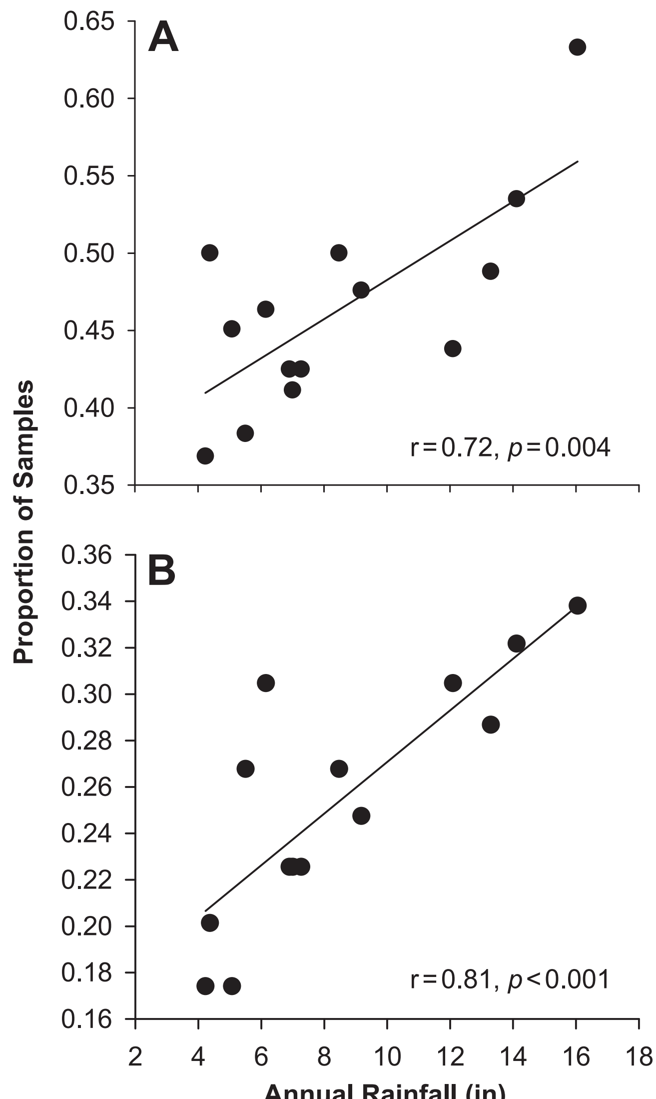

Figure 3.3
Relationship between annual rainfall from 1996 to 2009 and the proportion of elevated FIBs (A) and the proportion of samples that met the FTR criteria for contaminated seawater (B). Note that the data have been arcsine transformed. Rain was measured at Lindbergh Field, San Diego, CA.

material), and partially treated effluent from the San Antonio de los Buenos Wastewater Treatment Plant (SABWTP).

Bacterial contamination that occurred along the shore during periods of warmer, dry conditions between May–October occurred at only a few of the most southern stations (see Table 3.1). For example, the four samples with elevated FIB densities that were not associated with rainfall occurred at stations S0 and S2, both of which are located south of the international border. There are several potential sources of FIBs near these stations, including uncontrolled residential and commercial discharge points in Mexico and/or northward transport of SABWTP associated wastewater discharge to the ocean via Los Buenos Creek (Terrill et al. 2009).

Kelp Bed Stations

There was no evidence that the wastewater plume from the SBOO impacted the three kelp bed stations in 2009. Instead, elevated FIB densities at these sites corresponded to periods of heavy rainfall similar to the pattern seen along the shore. For example, all but one sample with elevated FIBs and all samples that met the FTR criteria at these stations occurred during the wet season (Table 3.2). High FIB counts in the kelp bed also tend to correspond with turbidity plumes from the Tijuana River and Los Buenos Creek (in Mexico). For example, a MODIS satellite image taken February 18 showed turbidity plumes encompassing all of the SBOO kelp stations, two of which had elevated total coliform concentrations on the previous day (Figure 3.4). As mentioned above, this turbidity plume likely started earlier in the week due to a major storm that began February 16. In contrast, only one seawater sample collected in the dry season from these stations contained elevated levels of FIB (Appendix B.3).

Additionally, about half of the elevated FIBs reported at the kelp bed stations were for total coliform bacteria (i.e., 11 of 19 samples); 7 of these 11 samples also had elevated fecal coliforms, of which 4 also exceeded the FTR criteria. Densities of enterococcus bacteria were elevated in 18 samples, 8 of which did not co-occur with elevated total or fecal coliforms.

Table 3.2

The number of samples with elevated bacteria collected at SBOO kelp stations during 2009. Elevated FIB = the total number of samples with elevated FIB densities; contaminated = the total number of samples that meet the fecal:total coliform ratio criteria indicative of contaminated seawater; Wet = January–April and November–December; Dry = May–October; *n* = total number of samples. Rain data are from Lindbergh Field, San Diego, CA.

Station	Depth		Season: Wet	Season: Dry	Total
I25	2 m	Elevated FIB	2	1	3
		Contaminated	1	—	1
	6 m	Elevated FIB	4	—	4
		Contaminated	—	—	—
	9 m	Elevated FIB	4	—	4
		Contaminated	1	—	1
I26	2 m	Elevated FIB	2	—	2
		Contaminated	1	—	1
	6 m	Elevated FIB	2	—	2
		Contaminated	—	—	—
	9 m	Elevated FIB	2	—	2
		Contaminated	—	—	—
I39	2 m	Elevated FIB	—	—	—
		Contaminated	—	—	—
	12 m	Elevated FIB	—	—	—
		Contaminated	—	—	—
	18 m	Elevated FIB	2	—	2
		Contaminated	1	—	1
Total Counts		Rain (in)	5.43	0.07	5.50
		Elevated FIB	18	1	19
		Contaminated	4	—	4
		n	270	270	540

Total suspended solids (TSS) and oil and grease (O&G) are also measured at the kelp bed stations as potential indicators of wastewater. However, previous analyses have demonstrated that these parameters have limited utility as indicators of the wastefield (City of San Diego 2007). TSS varied considerably during 2009, ranging between 1.8 and 29.9 mg/L per sample (Table 3.3), while O&G was not detected in any samples. Of the 44 seawater samples with elevated TSS concentrations

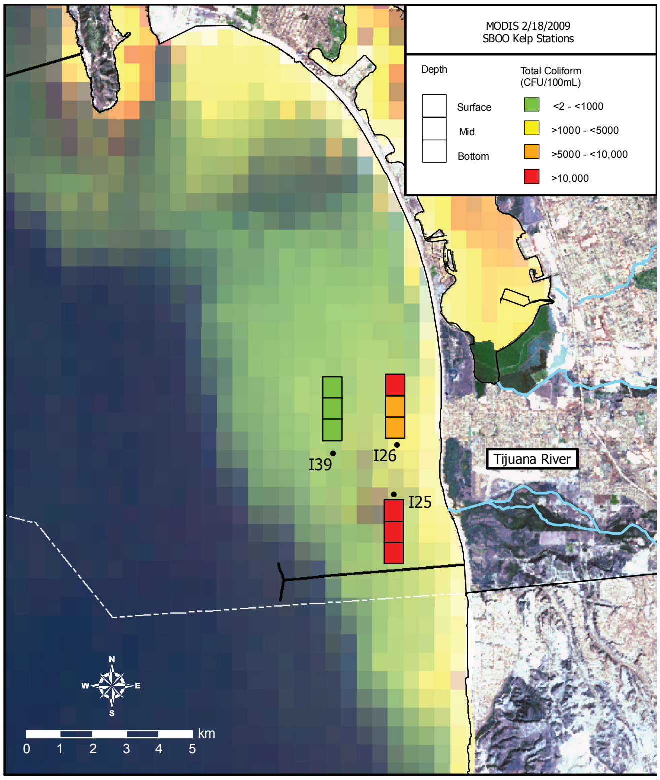

Figure 3.4
MODIS satellite image showing the SBOO monitoring region on February 18, 2009 (Ocean Imaging 2010) combined with total coliform concentrations at kelp stations sampled on February 17, 2009. Turbid waters from the Tijuana River and Los Buenos Creek can be seen moving northwest along the coastline overlapping the kelp bed stations. Waters are relatively clear over the outfall discharge site.

($\geq$8.0 mg/L), only two corresponded to samples with elevated FIBs. In contrast, 18 of these high TSS samples occurred at bottom depths, likely due to the re-suspension of bottom sediments when the CTD reached (touched) the sea floor. The remaining 26 high TSS values were found in surface-water and mid-water samples, and tended to be associated either with the presence of phytoplankton blooms or runoff from storm activity that occurred around the time of sampling.

Offshore Stations

Elevated FIB concentrations were rare in samples collected from the 25 non-kelp bed offshore stations during 2009. Only 51 of 897 samples (~5.7%) collected at these sites had elevated FIBs and 22 (~2.5%) met the FTR criteria for contaminated waters (Table 3.4, Appendix B.4). Most samples with elevated FIB levels were collected during the wet season at stations located along the 9 and 19-m depth contours (i.e., stations I5, I11, I18, I19, I24, I32, I40). As with the shore and kelp bed stations, the results from MODIS satellite imaging suggests that the nearshore region is affected by contaminants (turbidity plumes) originating from the Tijuana River and Los Buenos Creek. For example, a MODIS satellite image taken December 18, 2009 showed a turbidity plume associated with increased rainfall moving northwest and encompassing stations I19, I24 and I40 (Figure 3.5). Samples collected that day at these three stations had elevated total coliform densities at one or more depths, whereas the majority of samples collected farther offshore (i.e., stations I14, I16, I18, I22, I23) had low FIB levels. In contrast, only seven samples with elevated FIBs were collected during the dry season at the non-outfall stations. These included one or more samples each from stations I9 and I18 located south of the outfall along the 28 and 19-m depth contours, respectively, and one sample each from stations I22, I30, and I33 located north of the outfall along the 28-m depth contour (see Appendix B.4). One sample with elevated FIBs was collected at station I5 located along the

Table 3.3
Summary of total suspended solid (TSS) concentrations in samples collected from the SBOO kelp bed stations in 2009. Data include the number of detected values (*n*), as well as minimum (Min), maximum (Max), and mean detected concentrations for each month. The method detection limit = 1.6 mg/L for TSS.

	n	Min	Max	Mean
January	9	3.4	22.1	9.6
February	9	3.1	6.8	4.6
March	9	1.8	12.9	5.7
April	9	5.1	10.3	7.9
May	9	7.0	20.2	10.7
June	9	3.0	8.4	5.9
July	9	4.4	9.1	6.7
August	9	3.3	11.3	5.9
September	9	5.6	17.3	8.4
October	9	7.1	19.3	12.9
November	9	5.1	17.9	9.3
December	9	4.4	29.9	11.6

Table 3.4

The number of samples with elevated bacteria collected at SBOO offshore stations during 2009. Elevated FIB = the total number of samples with elevated FIB densities; contaminated = the total number of samples that meet the fecal:total coliform ratio criteria indicative of contaminated seawater; Wet = January–April and November–December; Dry = May–October; *n* = total number of samples. Rain data are from Lindbergh Field, San Diego, CA. Offshore stations not listed had no samples with elevated FIB concentrations.

		Season		
Station		**Wet**	**Dry**	**Total**
	9-m Depth Contour			
I11	Elevated FIB	6	—	6
	Contaminated	2	—	2
I19	Elevated FIB	7	—	7
	Contaminated	1	—	1
I24	Elevated FIB	1	—	1
	Contaminated	—	—	—
I32	Elevated FIB	2	—	2
	Contaminated	—	—	—
I40	Elevated FIB	4	—	4
	Contaminated	1	—	1
	19-m Depth Contour			
I5	Elevated FIB	2	1	3
	Contaminated	—	—	—
I18	Elevated FIB	1	1	2
	Contaminated	—	—	—
	28-m Depth Contour			
I9	Elevated FIB	2	1	3
	Contaminated	—	1	1
I12	Elevated FIB	9	3	12
	Contaminated	8	3	11
I14	Elevated FIB	1	2	3
	Contaminated	—	1	1
I16	Elevated FIB	2	2	4
	Contaminated	2	2	4
I22	Elevated FIB	—	1	1
	Contaminated	—	—	—
I30	Elevated FIB	—	1	1
	Contaminated	—	—	—
I33	Elevated FIB	1	1	2
	Contaminated	1	—	1
	Rain (in)	5.43	0.07	5.50
Total Counts	Elevated FIB	38	13	51
	Contaminated	15	7	22
	n	252	252	504

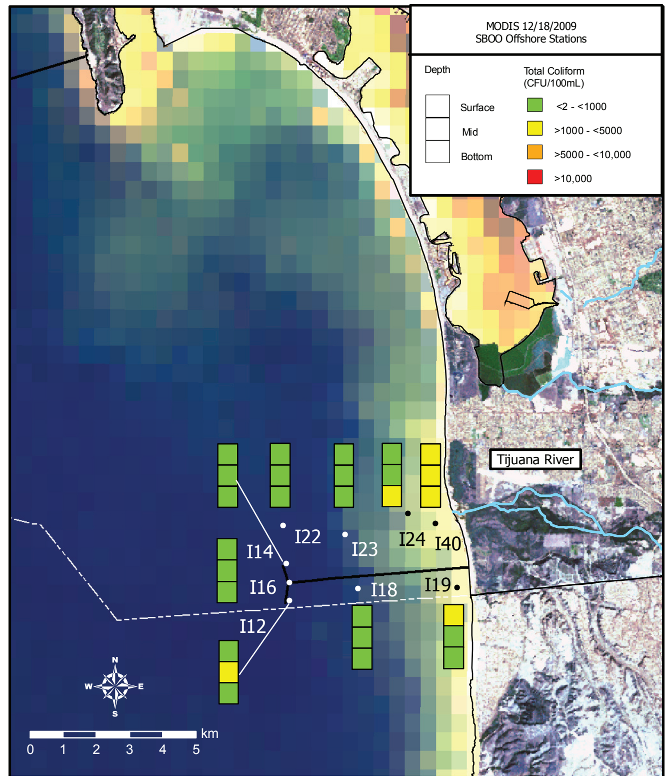

Figure 3.5

MODIS satellite image showing the SBOO monitoring region on December 18, 2009 (Ocean Imaging 2010) combined with total coliform concentrations at offshore stations sampled on the same day. Turbid waters from the Tijuana River and Los Buenos Creek can be seen moving north along the coastline and overlapping stations where contamination was high nearshore. Waters are clear over the outfall discharge site.

19-m depth contour in Mexican waters. Elevated FIB levels at I5 during the current and previous years (e.g., see City of San Diego 2007) are likely related to contaminated outflows from the nearby Los Buenos Creek.

During 2009, a total of 19 samples with elevated FIB densities were collected at sites adjacent to the SBOO diffusers (i.e., stations I12, I14, I16). Most of these samples were collected from a depth of 18 m or greater, and most also met the FTR criteria for contaminated waters (see Appendix B.4). Consequently, it appears likely that these FIB densities were associated with wastewater discharge from the outfall. Further, two samples with elevated FIBs were collected in surface waters during the year; both of these were collected at station I12 in February and were likely associated with the surfacing of the wastewater plume in the winter.

Aerial imagery results support this conclusion, as they indicated that the wastewater plume reached near-surface waters above the discharge site on several occasions between January–April and November–December (Svejkovsky 2010). The low incidence of contaminated waters during winter at the surface and at depth may be due to chlorination of IWTP effluent, which typically occurs between November and April each year. The lack of elevated bacteria levels in surface waters during the summer is expected, as those are the months when the water column is well stratified and the wastefield remains trapped beneath the thermocline.

Like the kelp bed stations, TSS and O&G are also measured at the offshore stations as potential indicators of wastewater. TSS was detected frequently at the offshore stations in 2009 at concentrations that varied considerably between 0.2 to 33.5 mg/L per sample (Table 3.5). In contrast, O&G was detected in only one sample at a concentration of 1.6 mg/L. Of the 284 seawater samples with elevated TSS concentrations (≥ 8.0 mg/L), 22 corresponded to samples with elevated FIBs, one of which met the FTR criteria for contamination. Conversely, 113 of these high TSS samples occurred at bottom depths; these high concentrations were likely due to the re-suspension of bottom sediments when the CTD touched the sea floor. The remaining 171 high TSS values were found in surface-water and mid-water samples, and tended to be associated either with the presence of phytoplankton blooms or runoff from storm activity that occurred around the time of sampling.

Table 3.5

Summary of total suspended solid (TSS) concentrations in samples collected from the SBOO offshore stations in 2009. Data include the number of detected values (*n*), as well as minimum (Min), maximum (Max), and mean detected concentrations for each month. The method detection limit = 1.6 mg/L for TSS.

	n	Min	Max	Mean
January	75	1.6	28.4	6.2
February	72	0.2	16.1	5.3
March	75	0.2	47.7	7.2
April	75	1.9	19.0	6.5
May	75	0.2	19.3	7.4
June	75	0.2	15.7	5.2
July	75	0.2	16.5	6.5
August	75	0.2	12.5	6.1
September	75	2.1	18.5	8.3
October	75	2.6	24.4	7.3
November	75	2.8	18.2	8.1
December	75	2.6	33.5	9.9

California Ocean Plan Compliance

Compliance with the 2001 COP water contact standards for samples collected from January through December 2009 at the SBOO shore stations located north of the USA/Mexico border and at the three offshore kelp bed stations is summarized in Appendix B.5. Overall, compliance in 2009 was similar to compliance in 2008 (see City of San Diego 2009) despite the decrease in rainfall this year (i.e., 5.5 inches in 2009 vs. 12.1 inches in 2008). During 2009, compliance along the shore ranged from 61 to 98% for the 30-day total coliform standard, 56 to 88% for the 60-day fecal coliform standard, and 75 to 100% for the 30-day fecal geometric mean standard. In addition, the shore station samples were out of compliance with the 10,000 total coliform standard 19 times during the year. Differences in compliance rates during the year generally reflected trends in elevated FIBs; i.e., compliance was lowest between January–March and December when rainfall was greatest, especially at stations closest to the Tijuana River (i.e., S5, S6, S11) and to the south (i.e., S4, S10) (see previous discussion).

Compliance rates for samples collected at the three kelp bed stations tended to be higher than at the shore stations, which reflects the lower levels of FIBs found in these samples. Compliance at these sites during 2009 ranged from 80 to 98% for the 30-day total coliform standard, 80 to 98% for the 60-day fecal coliform standard, and 100% for the 30-day fecal geometric mean standard. In addition, the kelp bed stations were never out of compliance with the 10,000 total coliform standard. As with the shore stations, the lowest compliance rates tended to occur during months with the most rain at stations I25 and I26 located nearest the Tijuana River.

Summary and Conclusions

There was no evidence that wastewater discharged to the ocean via the SBOO reached the shoreline or nearshore recreational waters in 2009. Although elevated FIB densities were detected along the shore, and occasionally at the kelp bed or other nearshore stations, these data likely do not indicate shoreward transport of the SBOO wastewater plume. Instead, analysis of FIB distributions and the results of satellite imagery data indicate that other sources such as outflows from the Tijuana River and Los Buenos Creek, as well as surface runoff associated with rainfall events are more likely to have impacted water quality along and near the shore in the South Bay region. For example, the shore stations located near the Tijuana River and Los Buenos Creek have historically had higher numbers of contaminated samples than stations located farther to the north. Further, long-term analyses of various water quality parameters have demonstrated that the general relationship between rainfall and elevated FIB levels has remained consistent since ocean monitoring began in 1995, including the period prior to wastewater discharge (e.g., see City of San Diego 2000). Finally, no indication of shoreward movement of the plume was evident in remote sensing images (see Svejkovsky 2010).

During 2009, the majority of elevated FIB densities not associated with rainfall events occurred at several offshore sites located within 1000 m of the SBOO diffusers at a depth of 18 m. Additionally, only two samples with elevated FIBs were collected near or at the surface during the year, although remote sensing observations did detect the signature of the wastewater plume in near-surface waters over the discharge site on several occasions during the winter. As discussed in the previous section, the low incidences of contaminated seawater at these times were most likely due to chlorination of IWTP effluent that typically occurs during the winter. In contrast, the lack of contaminated surface waters during the summer is expected due to wastefield entrapment beneath the thermocline.

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